Cylindrical Grinding Open Architecture and Feed Rate Control by Power Feedback

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Motivation of Research

- Open architecture of the machine for universal controllers
- Feed rate control of wheel dressing and plunge grinding
- Feed rate control by power feedback of the grinding wheel
- Gap elimination
Open Architecture Interface

- Selection of Controller
  - Amplifiers (added)
  - Sensors (added)
    - Encoders
    - Tachometer
    - Commutators

- Interface
  - 16 BNC voltage connectors
  - 74 I/O digital connectors
    - Isolated
  - 4 encoder connectors

- Manual kill switch box
Open Architecture Wiring

Controller Card
- Computer
- Amplifier
- Frequency Drive
- Tachometer
- Power Meter

Factory Controller
- Amplifier
- Selector
- Table
- Limits

Position
- Motor

Commutation Sensor
- Digital Inputs
General System Characteristics

• Motion
  – Two tables
  – Rotating workpiece
  – Rotating tool

• Friction
  – High static friction
  – Low dynamic friction

• High inertia

• Low speed process
Controller Hardware Choice

• General Controller Boards
  – PID with acceleration and velocity feed forward
  – Limited and defined digital I/O
  – Limited and defined voltage I/O
  – Limited variability

• Dspace
  – Numerous generic digital I/O
  – Numerous generic voltage I/O
  – Simulink based
  – Visual Basic interface
  – Unlimited variability
PID Power Control Feedback

- System modeling
- Parameter identification
- Controller design
- Simulations
- Implementation

\[ v = \text{Infeed velocity} \]
\[ \omega_H = \text{Workhead velocity} \]
\[ \omega_S = \text{Spindle velocity} \]
Servo Dynamics Estimation

\[ G(s) = \frac{4200}{s + 17} \left[ \frac{mm}{sec} \right] \]
Power Meter Dynamics

\[ G(s) = \frac{20}{s + 20} \begin{bmatrix} \text{power measurement} \\ \text{power} \end{bmatrix} \]
Grinding Process Estimation

\[ G(s) = \frac{77400}{s + 1.9} \quad \left[ \frac{\text{watts}}{\text{mm/} \text{sec}} \right] \]
Controller Design

- **Velocity Control**
  - Kalman filter and state variable feedback
  - Close loop response of 50 msec

- **Power Control**
  - Open loop poles: -20, -20, -1.9
  - PI control: $K_p + K_i/s$
  - Settling time: 2 sec
  - $\zeta$: 0.8
  - $W_n$: 2.5
  - $K_p$: 1.1 $\times 10^{-7}$
  - $K_i$: 3.2 $\times 10^{-7}$
Simulations of Power Controlled System

- Input
  - Commanded power step
  - Perturbation power step
- Output
  - Power
  - Feedrate
Continuing and Future Research

• Implementing feed rate control by power feedback

• Designing and implementing adaptive controllers

• Controller process testing
  – Dressing
  – Gap elimination

• Creating a Visual Basic interface for power control